| | | | | |
|---|---|---|---|---|
| Enhanced Coagulation | Useful for removal of organic DBP precursors | TOC in Delta water not very amenable to coagulation; does not remove bromide | | + |
| Granular Activated Carbon Adsorption | Useful for removal of organic DBP precursors | Requires EBCT in excess of 15-20 min; does not remove bromide; limited usefulness for bromate removal | Requires regeneration at 3-6 mos. frequency | +++ |
| Microfiltration | Effective for *Giardia*, Cryptosporidium cyst removal | Ineffective for virus removal but can be coupled with post-chlorination for virus inactivation; ineffective for TOC removal but can be coupled with powdered carbon or coagulant for partial TOC removal; will not remove bromide; waste stream needs to be disposed of | Membrane process technology undergoing rapid changes, becoming more practical and less expensive | +++ |
| Nanofiltration And Ultrafiltration | Effective for *Giardia*, Cryptosporidium cyst removal and virus removal; NF effective for TOC removal at MWCO less than 200-500 Daltons; NF provides some bromide removal | UF will not remove bromide; requires pre-treatment to prevent membrane fouling; relatively low product recovery; waste stream needs to be disposed of | Membrane process technology undergoing rapid changes, becoming more practical and less expensive | ++++ |
| Reverse Osmosis | Effective for *Giardia*, Cryptosporidium cyst removal and virus removal; effective for removal of TOC and bromide | Requires pre-treatment to prevent membrane fouling; relatively low product recovery; waste stream needs to be disposed of | Membrane process technology undergoing rapid changes, becoming more practical and less expensive | +++++ |

* Relative costs are indicated by number of + entries

Table 5. Possible Treatment Options for Meeting Proposed or Future Rules.

| PROPOSED OR FUTURE RULE | POSSIBLE TREATMENT OPTIONS |
|---|---|
| Interim Enhanced Surface Water Treatment Rule | No change in disinfection practice |
| LT2ESWTR | Treatment may depend on level of fecal contamination in source water: Ozonation; Chlorine Dioxide, Microfiltration; Possibly Emerging UV Disinfection |
| Stage 1 D/DBP Rule, with 10 ug/L bromate MCL | Chlorination with secondary chloramination; ozonation with/without biofiltration coupled with secondary chloramination with need for bromate control |
| Stage 2 D/DBP Rule (as proposed in 1994), with 5 ug/l bromate MCL. Stage 2 will be reproposed and these criteria may differ significantly from 1994 proposed criteria. . | Ozonation with/without biofiltration coupled with secondary chloramination with need for bromate control; nanofiltration with post-chloramination; microfiltration with chlorine and chloramines; and possibly emerging UV disinfection with post-chloramination |

In summary, treatment processes are available to treat Delta water that will produce safe drinking water and minimize the risks to public health, although treatment costs may significantly increase with implementation of advanced treatment.

## 6.0 Treatment versus Source Control

General source control options for $Br^-$ are largely limited to segregation of Delta water intended for export from saltwater intrusion. Another course of action is represented by storage intended to dampen seasonal variations in $Br^-$. Of course, within this general approach are many specific options that are largely embodied within the CALFED alternatives. Source control options for NOM include (on-site) treatment or diversion of agricultural drainage (or modified drainage practice) and algae control.

Even with selection of a CALFED alternative, there will still need to be a short-term strategy for utilities to meet Stage 1 and Stage 2 DBP regulations before alternative implementation. Much will depend on differences between the Stage 1 versus Stage 2 MCLs, and the Cryptosporidium-based disinfection requirements that will evolve through the ESWTR. During this same time period, additional health effects data will be forthcoming on HAA species and $BrO_3^-$, which may lead to either a relaxation or further restriction of current MCLs.

Enhanced coagulation, low-pH ozonation, and optimal use of multiple disinfectants will likely be the minimum technology required. Given that ozonation presently appears to be the only viable inactivation option for Cryptosporidium, it is likely that ozone use will continue to increase. Finally, there are exciting new developments in membrane and UV technology that may play a role in Delta-water treatment in the area of selective membranes (e.g., UF) that are less prone to fouling, capable of physical removal of microbes, and provide high (> 90 %) water recoveries.

## 7.0 Recommendations and Research Needs

### 7.1 Recommendations

The Cal-Fed program must examine issues as they are likely to develop over a 20 to 30 year horizon. The problems in the Delta are immense and will require a very large reliance on research that involves many disciplines. Short-term decisions will have to be geared toward meeting regulations that should be largely anticipated from stage II of the M/DBP rule. However, as the program develops its research agenda, its short-term research agenda must be consistent with providing more definition for decisions that impact water quality 20 to 30 years from now.

It is recommended that CALFED articulate a clear, short-term plan, comprised of both treatment and source control approaches, to deal with bromide-related drinking water issues before and during implementation of the various CALFED alternatives. It is not the charge of the expert panel to make an unqualified recommendation to CALFED on an alternative; however, considering *only* drinking water quality, it is clear that Alternative 3 would provide the most benefit with regard to the beneficial use of Delta water for drinking water supply, although Alternative 2 would provide more benefit at certain export points (e.g., CCC). Other hydraulic management options not included in the three Alternatives might also provide improvement in source water quality over that currently obtainable from the Delta. While it is not in the charge of this panel to identify such options, CALFED may wish to develop and consider such options within the phased process now under consideration for the CALFED long-term plan.

## 7.2 Research Needs

The panel recommends that a) CALFED follow and promote important health effects research that is ongoing/planned to focus on brominated DBPs, b) source-specific (e.g., SWP) DBP models be developed to assess various treatment and source control options, and c) given the importance of NOM, a NOM inventory of Delta water be performed to elucidate the spatial and seasonal distribution of NOM, both amount (TOC) and properties (e.g., $UVA_{254}$, DBP formation potential), followed by development of a model to predict TOC concentrations throughout the Delta.

Given that co-occurrence of pathogens and DBP precursors may significantly influence the feasibility of simultaneously controlling for both DBPs and pathogens under future drinking water regulations, the panel also recommends that CALFED a) obtain information indicating the level and variability of fecal contamination (including measurement of *Cryptosporidium* and *Giardia* [using best available methods] and *E. coli)* in source waters, b) obtain information on the co-occurrence of bromide, TOC, $UVA_{254}$, and microbes in source waters, and c) determine the extent to which pathogens and DBP precursors can feasibly be reduced in source waters of utilities.

Given the potential for membrane technology, it is recommended that NF and UF membrane processes be assessed for their collective ability to remove $Br^-$, TOC, and microbes from Delta water. Given the potential constraint of bromate formation, CalFed should evaluate $BrO_3^-$ control strategies to meet a range of potentially more restrictive MCLs.

CALFED should resolve the concern regarding whether or not (or how much of) "recycled bromide from agricultural return drains is actually "recycled" or is from agricultural fumigation activities using methyl bromide.

CALFED should encourage and cooperate with epidemiological investigations of cancer, reproductive and developmental toxicities that may be associated with disinfectant by-products. This cooperation should focus on adding bromide to established studies that have been conducted on a national scale rather than trying to initiate new epidemiological studies that focus only on the Bay-Delta area. It is important to pursue reproductive and developmental toxicity issues as well as carcinogenic effects of disinfectant by-products in any research program. The low-dose carcinogenic risk of bromate is a critical issue if bromide-containing waters are to be

ozonated. Investment in careful studies of the type that have been done for chloroform, dichloroacetate and trichloroacetate, but following hypotheses more appropriate for bromate induced tumorigenesis, could possibly raise the MCL.

## 8.0 References


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